ABSTRACT

Rahul Kumar Kaushal

Roll No. 13310015

Discipline of Earth sciences

Indian Institute of Technology Gandhinagar

Thesis Supervisors

Dr. Vikrant Jain

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Investigating linkages between surface-subsurface processes and its control on geomorphic evolution of river systems in the tectonically active Nahan salient, NW Himalaya, India

This thesis presents geomorphic analysis to understand subsurface neotectonic deformation in the Nahan salient, a tectonically active window of the Sub-Himalaya. The Sub-Himalaya and its south bounding Main Frontal thrust (MFT) is the most tectonically active region of the Himalaya, as total shortening across the Himalaya (~14-21 mm/yr) is mostly accommodated within the Sub-Himalayan thrusts. However, the process understanding of deformation pattern, stress partitioning and shortening rates along active thrusts in the Sub-Himalaya are still lacking or poorly constrained in some windows of the Himalayan arc. A detailed tectono-geomorphic investigation is needed for all such windows, and the Nahan salient is one such less studied area.

My study on the Earth's surface (geomorphology)–subsurface (tectonic) process interaction includes structural mapping, estimation of various geomorphic indices, landform mapping in lab and field, OSL chronology, bed-material grain size analysis, quantification of rock erodibility, semi-quantitative modelling and 1-D modelling of long profile though incorporation of hydrological and hydraulic parameters. Initial analysis using geomorphic indices, structural mapping and field investigations suggest that the Nahan salient is actively undergoing neotectonic deformation along a number of thrust

faults in the Sub-Himalaya. The western part of the Nahan salient has been relatively more deformed and significantly uplifted during neotectonic activity. I have also proposed a new buried fault in the central part of the Nahan salient. The major deformation in the Nahan salient seems to be along thrusts at the north of the MFT.

Further, quantitative information of neotectonic deformation was achieved by analyzing chronologically-constrained fluvial landforms. The geometry of uplifted river terraces was mapped using high-precision, Real Time Kinematic Global Positioning System (RTK-GPS) and chronology were established through optically stimulated luminescence (OSL) dating of the fluvial sediments overlying the strath. Field data based structural cross-sections were superimposed with uplifted terraces to estimate uplift /shortening rates. The estimated Holocene average uplift rates are consistently higher in late Holocene as ~6-7 mm/yr (averaged over ~2-4 ka) in comparison to Early Holocene rate as ~1 mm/yr (averaged over ~11-12 ka) on the MFT (~30 km) within the Nahan salient. Late Holocene average uplift rates are also spatially variable along the MFT and it is higher in the northwest and southeast part of the Nahan salient. Minimum late Holocene average shortening rate across the MFT ranges from ~1-3 mm/yr (averaged over ~11-12 ka) to ~10-11 mm/yr (averaged over ~2-4 ka) (considering MFT fault plane dip 30°). These rates are in agreement with the Holocene slip rate of ~9 mm/yr from nearby area (Dehradun recess). This study also suggests that most of the ongoing crustal shortening (~14 mm/yr) is accommodated along the MFT during late Holocene, and hence the MFT is the most active fault in the Sub-Himalaya of the Nahan salient.

I have extended regional understanding from the Nahan salient to further analyse linkages of surface-subsurface processes through a semi-quantitative approach by incorporating the hydrology and hydraulic parameters. River response to tectonic perturbation is reflected in slope and channel width variability. Though, sensitivity of these parameters will vary in rocks having different erodibility. Hydraulic parameters like shear stress and unit stream power are sensitive to uplift rates as well as to rock erodibility. Peaks in downstream variability of these parameters can be used as a proxy to identify active uplift along the faults, though regional variability in these parameters will reflect variation in rock erodibility. These hydraulic and hydrological indices were further used to identify and classify channel reaches into transport-limited and detachment-limited, because the cause-effect relationship between morphology and subsurface tectonics may vary from transport-limited to detachment-limited rivers.

Long profile is the most important and sensitive landform to tectonic disturbances. Hence, I have simulated long profile evolution process for transport-limited reaches through a 1-D model using the stochastic distribution of discharge. I infer that channel steepness is not only sensitive to uplift rate but also to grain size. Hence, gradient of the transport-limited river can be set by changing grain size, even if uplift rate is constant. Further, new quantitative data on erodibility and abrasion rates highlight the role of lithology in river bed-material characteristics and hence on river sensitivity to tectonic perturbation. Semi-quantitative and 1-D model suggests that river morphology and incision patterns are also controlled by the lithological variability by modifying the shear stress/unit stream power.

My thesis finally presents a multi-disciplinary approach to (a) develop tectono-geomorphic understanding of a tectonic active area and (b) to address key research questions on the sensitivity of fluvial landforms to tectonic perturbation. It highlights that in-depth understanding of Earth's surface-subsurface processes could be achieved through multi-disciplinary study by including structural geology, geomorphology, GIS, hydrology and hydraulics through integration of lab, office (modelling) and field investigations.